Construction Simulation 3D of Tight-Fitting Sportswear to Evaluate Tension Distribution of Elastic Fabric

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Abstract

Elastic fabrics are considered to be of high importance to produce sportswear garment for comfortable properties and body fitting to human body. Fabric elasticity is an important parameter, which plays a key role particularly when constructing patterns for tight-fitting clothing, in respect of changing pattern-piece size, resp. adapting the garment to the contours of a body in motion. The purpose of this research is to design 3D pattern construction with stretch fabric for women of aerobic sportswear using OptiTex software to represent the tension properties of fabric generated on the surface of the simulation model. Moreover, the study on mechanical properties of elastic fabric by FAST system and its result have illustrated that OptiTex could be used to simulate the tension map options so as to inspect its colored map depicting amounts of tension between clothing and model. It is certainly obvious that tension map area could be adjusted in accordance to the pattern design suitable for tight-fitting clothing wearing. Moreover, the outcomes of stretch fabrics could be compared with the influence of extensibility between warp and weft directions.

Keywords: Pattern Construction, Elastic fabric, Tight-fitting garment, Sportswear, Tension, Stretch fabric.

1. Introduction

Elastic garments for sportswear has been providing comfortable movement, minimizing the risk of injury or muscle fatigue, and reducing friction between body and clothing. The three main indicators affecting clothing comfort assessment include thermal-wet comfort, tactile comfort and pressure comfort [1]. However, one of the very most important indicators that help facilitate the assessment of clothing comfort is pressure comfort [2, 3, 4]. In order to produce comfortable tight-fitting garments with suitable pressure comfort, stretch fabrics are considered to be of high importance [2, 5]. However, stretch fabrics can be assessed through 3D simulation technology to find its best pressure comfort and therefore, the 3D simulation technology of clothing not only is used for creating pattern but also to simulate the texture look of final virtual garment of fabric properties. The 3D simulation technology would be able to predict and adapt clothing pattern suitably according to B. Musilová who used regression equations to

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predict the pattern dimension due to the change of mechanical properties of a stretch fabric, whilst each of them consists of the sum of characteristics that influence a pattern shape [6]. R. Nemčoková measured the fabrics using the Kawabata Evaluation System for Fabrics (KES FB-Auto) and also applied the Design Concept3D software to enable the visualization of these models which showed the pressure, curvature, strain or tension and the elongation related to the mechanical properties of fabrics [7]. Moreover, Fabric Assurance by Simple Testing (FAST) system had been used to find out mechanical properties of fabrics [8, 9] and test the stretch fabric's mechanical properties with OptiTex softwear by draping simulation and tension map of clothing methods [2, 5, 10]. Y.Y. Wu. et al. attempted to use simulation skirt experiment finding out the mechanical properties of 20 types of woven fabrics. In the experiment, FAST and KES measurement methods were used to measure fabric physical properties. After measurement using FAST and KES, test results were inputted into the OptiTex software to define fabrics in the simulation experiment and FAST results were reported to be relatively more reliable, less expensive and simpler to operate compared with KES [11].

In accordance to the mentioned study, not only this research attempted to use FAST system to measure fabric physical properties but also to input the test results into the OptiTex software to find out the value of tension by setting 8 measuring points on the simulated women's sportswear so as to make comparison between each point and to evaluate the influence of body shape on tension distribution of clothing. Moreover, the result will be able to help predict suitable pattern construction for pressure comfortable on tight-fitting sportswear in the future.

2. Research Methodology

2.1 Materials

Elastic knitted fabrics consisting difference structure of knitted fabric between Single Jersey and Interlock were made of Polyamide (PA) and Elastane. Its composite varied from 92% PA, 8% Elastane of Single Jersey structure (Sample 1) and 80% PA, 20% Elastane of Interlock structure (Sample 2) respectively.

2.2 The quad load test procedure

Specimens in the wale, course, 45° bias and 135° bias were placed on the hanger and the 250 g weight was applied. After hanging one minute for the specimen to stabilize, the extended measurement between the benchmarks was recorded. The calculation of the stretch degree is simplified by Watkins's [12,13] using formula (1). The degree of stretch expressed as a percentage is calculated by subtracting the extended length from the original length 10 cm. (100 mm.).

$$\textit{Degree of stretch} = [\textit{Extended length} - 100]\ \% \qquad (1)$$

When, the extended length unit is (mm.)

2.3 FAST system method

The acquired properties of stretch fabrics from Optitex simulator software testing for input parameters was measured by the FAST-1 compression meter provides a direct measure of fabric thickness at 2 gf/cm^2 (196 Pa) and 100 gf/cm^2 (9.81 kPa) can be calculated fabric surface thickness at formula (2).

$$ST = T2 - T100 \qquad (2)$$

When, ST is surface thickness (mm.), T2 is average thickness (mm.) at 2 gf/cm^2 and T100 is average thickness (mm.) at 100 gf/cm^2.

The FAST-2 bending meter provides a direct measure of fabric bending length in either the wale or course direction. Bending rigidity is calculated from the bending length and fabric mass per unit area by formula (3).

$$B = W \times c^3 \times 9.81 \times 10^{-6} \tag{3}$$

When, B is bending rigidity (μN.m), W is mass per unit area (g/m^2) and c is bending length (mm.)

The FAST-3 extension meter provides a direct measure of fabric extension under selected loads with wale and course directions. Shear rigidity is calculated from formula (4) which using extension on the bias at 5 gf/cm should be calculated.

$$G = 123 \div EB5 \tag{4}$$

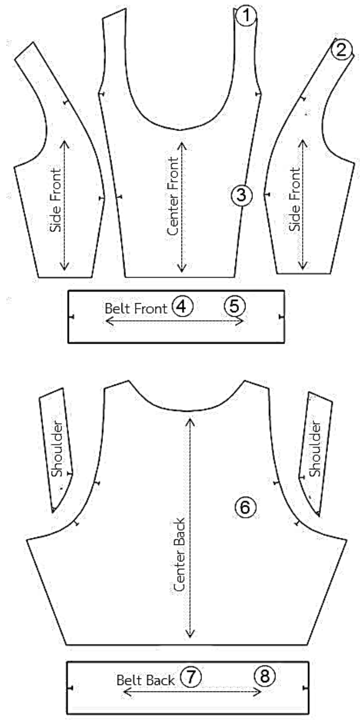
When, G is shear rigidity (N/m) and EB5 has extension on the bias at 5 gf/cm.

Extensibility is measured at loads 100 gf/cm in wale and course directions of stretch fabric by using tensile tester because the fabric specimens had very high extension value with loading at E100 (100gf/cm) from FAST-3 extension meter. Besides, the results of extensibility measurement under the load of 5 gf/cm in bias direction have also shown a difference outcome of only 1.15% when compared to standard deviation (SD) 0.59 and the coefficient of variation (CV%) 3.52 probed 10 time by FAST system. From this condition, it could be concluded that tensile tester could creditably be used to measure the extensibility under the load of 100 gf/cm.

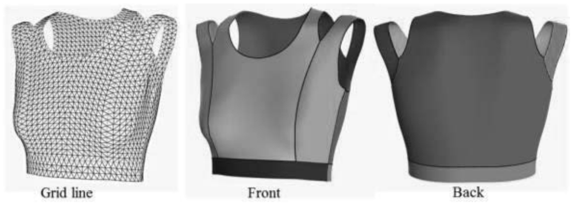
2.4 3D pattern construction and tension map

In designing pattern construction of this research we reduced the pattern dimension at 10% of the size measurements a standard amount from circumference length, only one size of pattern in accordance was utilized for comparison and simulation of mannequin body by changing input parameter of mechanical properties of the body size of 38 in accordance with European standard size.

The results of mechanical properties of elastic fabrics measured by FAST system and designing pattern construction as Figure 1(a) then converted properties for clothing simulation will be used in OptiTex 3D simulation to evaluate the tension map of clothing.



(a)



(b)

Figure 1. Pattern Construction of Sportswear [14]

The Figure 1(a) shows 2D pattern construction of dimension area with length front 28.50 cm from the center of front neck line to the center of front waist length, length back 40.00 cm. and bust circumference 79.20 cm. including waist circumference 63.00 cm. Figure 1(b) illustrates 3D pattern which simulated to garment product both front side and back side. The numerical data of pattern construction was used to calculate fabric utilization of clothing as shown in the Table 1.

TABLE 1. The Description of Sportswear Pattern

Piece name	Quantity	Area (cm^2)	Perimeter (cm)
Center front	1	472.47	134.62
Side front	2	233.31	78.93
Belt front	1	103.45	66.12
Center back	1	1,060.56	141.54
Shoulder back	2	47.90	37.07
Belt back	1	115.63	73.08
Total	8	2,314.53	647.36

3. Experiment and Results

The results of hanger load test in Table 2 was evaluated as graphics illustration throughout 360° of fabric orientation in the Figure 2 and this method measured four directions corresponding to 0°, 45°, 90° and 135° rotation while measurements were repeated 10 times in each direction.

TABLE 2. The Result Stretch Degree in Four Directions.

Elastic Fabric	Degree of stretch (%)			
	Course 0°	Bias 45°	Wale 90°	Bias 135°
92% PA, 8% Elastane (Single Jersey structure)				
Average	69.40	47.20	18.20	51.60
STDEV	1.58	0.79	0.42	0.52
% CV	2.27	1.67	2.32	1.00
80% PA, 20% Elastane (Interlock structure)				
Average	43.80	45.80	32.80	41.40
STDEV	0.42	0.79	0.79	0.52
% CV	0.96	1.72	2.40	1.25

The angular stretch distribution plots clearly demonstrate that the highest stretch is 92% PA, 8% Elastane in the course direction at 69.40 degree of stretch. Whereas, the direction of wale was merely at 18.20 degree which is the lowest degree of stretch, the line graph in the Figure 2 illustrates angular stretch distribution curves throughout 360° of fabric orientation which is compared between two fabrics. The fabric of 80% PA, 20% Elastane which is Interlock structurer, does not stretch as much as Single Jersey structurer 92% PA, 8% Elastane fabric, which can be stretch in all directions. Single Jersey structure has stretching ability in the course direction at 69.40% degree show as blue line in Figure 2 which is lesser in the wale direction. Even though Interlock fabric has higher Elastane than Single Jersey structurer but the result shown that the structure obviously has influence on extensibility.

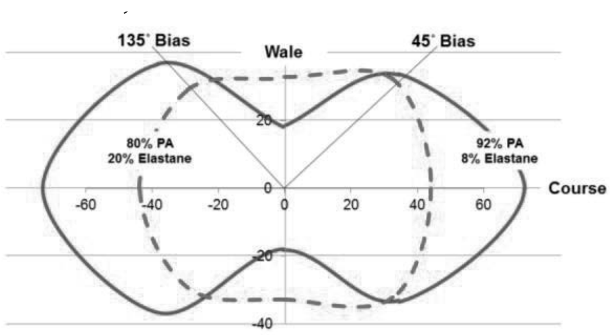


Figure 2. The Quad Angle Plots

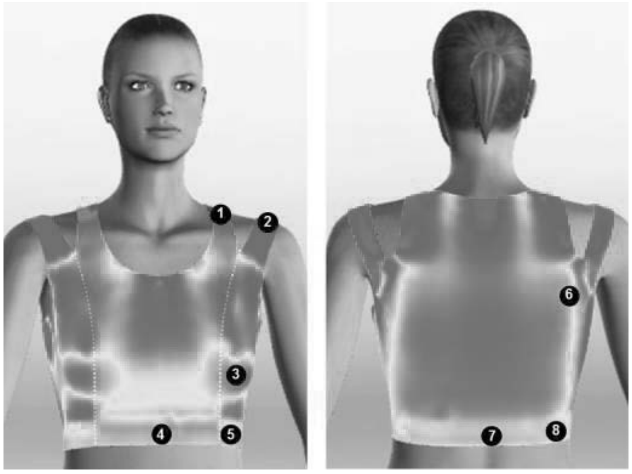
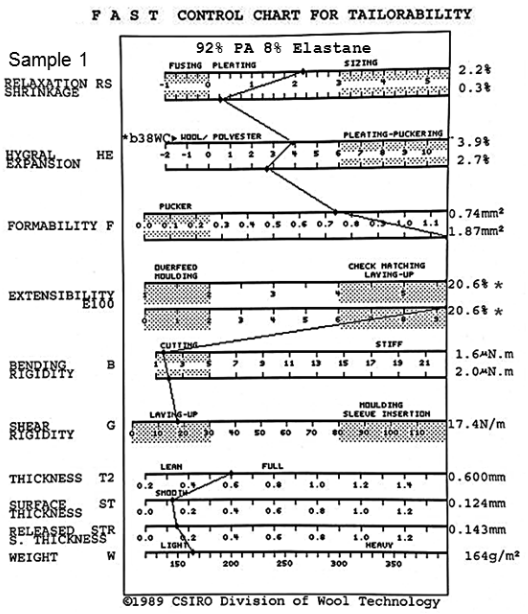
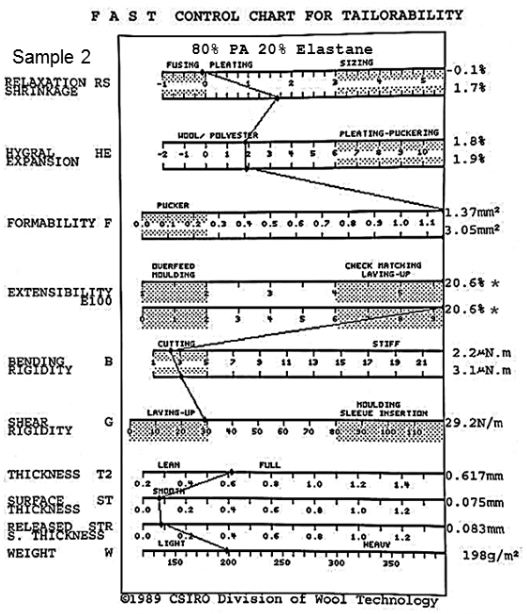


Figure 3. Tension Map Distribution

Parameters of elastic knitted fabric properties resulted from OptiTex simulator software had been used to determine the tension map on the virtual mannequin are as follows: According to Figure 3, results of FAST control chart had shown the fabric measured by FAST system. The value of extensibility marked (20.6%*) in Figure 4 (a,b) clarified that the tested fabrics had very high extensibility due to the limitation of equipment measurement performance and it could only be measured at 20.6% of extensibility value. Besides, we also simulated the value of tensile properties obtained by using the tensile tester as well as the OptiTex software which is used to input E100 extensibility to be calculated so as to simulate the tension map which had extensibility higher than 20.6%. The result of extensibility E100 from tensile tester of 92% PA, 8% Elastane fabric in wale direction is 22.90% and 70.86% in course direction. The fabric of 80% PA, 20% Elastane which is Interlock structurer of extensibility value 48.13% and 58.66% in wale and course direction respectively.



(a)



(b)

Figure 4. FAST System Control Chart

The results of mechanical properties value as shown in the Table 3 illustrated the parameters of fabrics and functions of fabric editor from OptiTex to convert fabric physical attributes from FAST parameter to OptiTex parameter for of 3D tension simulation.

TABLE 3. Knitted Properties from FAST System

Parameter of fabric	92% PA, 8% Elastane	80% PA, 20% Elastane
Bending (μN.m)		
X (Wale)	1.60	2.20
Y (Course)	2.00	3.10
Extensibility (%)		
X (Wale)	22.90	48.13
Y (Course)	70.86	58.66
Shear (N/m)	17.40	29.20
Friction	0.20	0.22
Weight (g/m^2)	164	198

Figure 5 highlights the results of tension values at the eight points which show the position of measurement in the Figure 3. The graph represents the value of tension at eight measuring points of body which can be compared by using grain line of straight grain line in vertical-wale direction of cloth as shown in Figure 6 and cross grain line in vertical-course direction for sewing garment. The graph shows that at 1st and 2nd points at the shoulder area, there are low tension values. While at the 3rd point, there is a bit high tension values at bust part of female body and point 4th – 8th the tension value also bear a resemblance to the 3rd. Due to the fact that contoured surface of a female human body is not a perfect cylinder, it is difficult to simulate tension on that particular surface. So the value of tension distribution of clothing from this experiment could not produce similar outcome when compare to one simulated with the cylinder shape. Therefore, it was found from analyzed result that the correlation of tension value between point 3rd and point 4th – 8th used equations from linear regression were determined when Y is variable of the value of tension at point 3rd and X is variable of tension value at point 4th – 8th. The linear relationship presented strong coefficient of determination (R^2) =0.82 from linear regression equation, y = 1.0589x - 2.7627.

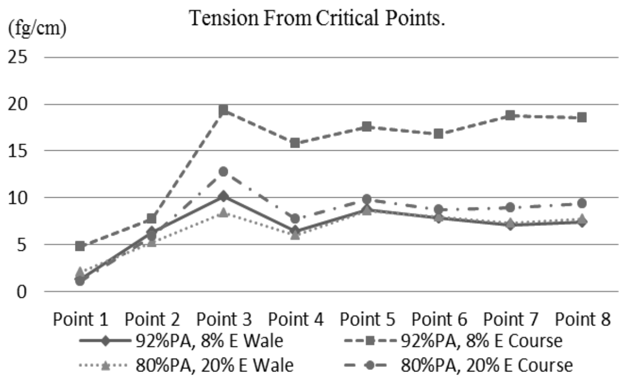


Figure 5. The Tension Simulation from 8 Critical Points

The maximum value tension of two samples elastic fabric with difference grain line between wale and course direction as show in Figure 6 which presented tension map gradient and inspect simulated cloth objects as a colored map depicting amounts of tension between the cloth and the model. The highest tension was 22.67 fg/cm in course direction of fabric, 92%PA, 8% Elastane with extensibility of 70.86% meaning the percentage of extensibility was higher, the result of tension also was higher than other direction. It could be concluded that the extensibility of fabric had the influence on the value of tension.

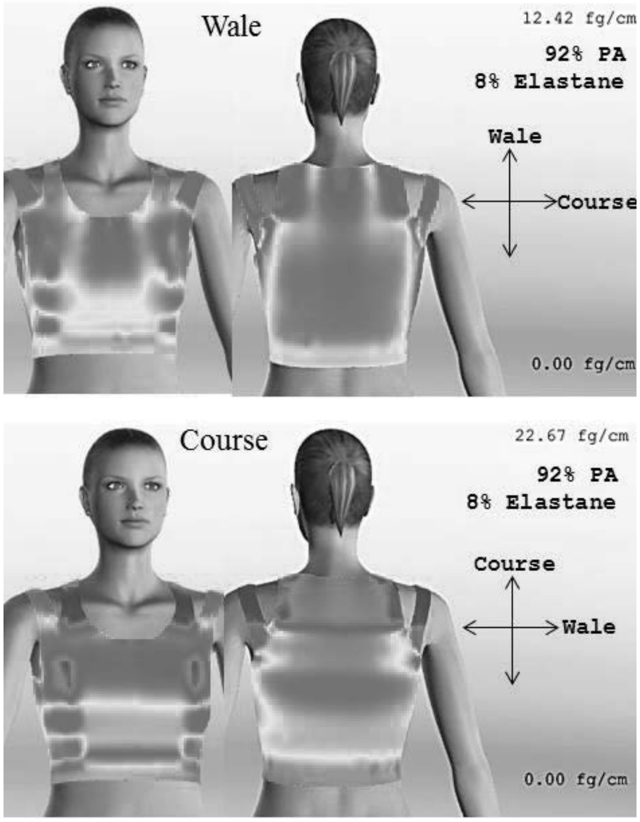


Figure 6. The 3D Simulation and Amount of Physical Tension Influencing the Cloth.

4. Conclusions

The outcomes of the simulation on the 3D pattern construction and the virtual mannequin evaluates tension mapping results. It is obvious that there are many factors that influence tension value such as Elastane, extensibility, body shape, pattern construction, grain line, etc. OptiTex as one of the most widely used software by clothing and textile researchers help find out the tension value reliably. It could be concluded that mechanical properties of fabric could be easy to use the extensibility value which the main importance influences on tension on clothing. Beside, female body shape has influenced on distribution of tension in different areas especially in the bust area where there was more stretch value than other area. When comparing the relationship between other points and bust area points, R^2 = 0.82 was found to be of high and reliable while 4^{th} point to 8^{th} point have well-distributed tension value.

The result of this research could practically be used to compare the result with other methods the further studies and used as a tool to evaluate pattern construction for tight-fitting sportswear.

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